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Report

of the

MSS Above 1 GHz Negotiated Rulemaking Committee

April 6, 1993

TABLE OF CONTENTS

List of Supplementary Information

0.0 SUMMARY

The Mobile Satellite Service (MSS) Above 1 GHz Negotiated Rulemaking Committee, chartered by the Federal Communications Commission, was in existence for 90 days for the purpose of providing technical recommendations and for recommending technical rules applicable to L-band (1610 - 1626.5 MHz) and S-band (2483.5 - 2500 MHz) for implementing the MSS and the radiodetermination satellite service (RDSS). The Committee examined, with respect to MSS/RDSS, technical aspects of intraservice sharing, interservice sharing, and feeder link and intersatellite link operations. The Committee's work provided rapid technical interchange among the MSS applicants and with the other affected services. Recommendations and technical rules were developed and supported by the Committee in the areas of interservice sharing, feeder links, and intersatellite links. Substantial technical analyses and evaluations were presented for intraservice sharing. Two approaches to intraservice sharing of the L-band frequencies for MSS/RDSS were examined, full band interference sharing and band segmentation. But consensus was not reached on frequency band sharing techniques to be implemented in the L-band. The inputs to the Committee should provide useful technical information for analysis and evaluation by the FCC in preparing its Notice of Proposed Rulemaking for the MSS above 1 GHz.

1.0 INTRODUCTION

The MSS Above 1 GHz Negotiated Rulemaking Committee (Committee) was chartered by the Federal Communications Commission (FCC or Commission) in January 1993 pursuant to the Negotiated Rulemaking Act of 1990 (NRA), Pub.L. 101-648, November 28, 1990. Negotiations were conducted through a Federal Advisory Committee chartered in accordance with the Federal Advisory Committee Act, 5 U.S.C. App.2. The Committee was convened to provide expert advice and recommendations to the FCC on technical matters related to the establishment and regulation of a mobile satellite service (MSS) in the 1610-1626.5/2483.5-2500 MHz frequency bands. (The Committee's charter is attached as Appendix 1.) The Committee's goal was to reach consensus on recommended technical rules. In accordance with the NRA, the Committee's recommendations are to serve as the basis for the proposals that the Commission includes in a forthcoming Notice of Proposed Rulemaking (NPRM).

By Public Notice dated August 7, 1992, the FCC announced its intent to establish this negotiated rulemaking committee. The FCC stated that through this procedure, it hoped to develop better regulations that may be implemented in a less adversarial setting. Specifically, the FCC indicated that the negotiations were intended to assist it in developing regulations that will facilitate the shared use of the spectrum by the maximum number of service providers. The FCC requested comment on whether it should proceed in this manner and requested applications for membership on the Committee from all parties that will be significantly affected by the outcome of the proceeding.

Based on these submissions, the FCC decided to proceed with the negotiated rulemaking. It announced the formation of the MSS Above 1 GHz Negotiated Rulemaking Committee by Public Notice dated December 15, 1992. A proposed meeting schedule was also provided in this Notice. All six pending MSS applicants, other users of the identified and adjacent frequency bands, one potential future MSS applicant, and one potential equipment manufacturer were included on the Committee. (A list of the Committee members is attached as Appendix 2.)

The Committee's charter was filed with Congress on January 6, 1993, the date of the Committee's initial meeting, and expired by its own terms on April 6, 1993. The Committee held ten full Committee meetings in the course of its three-month duration. In addition, the Committee adopted a Work Program that established three informal working groups (IWGs) to collect information and to draft proposals for technical rules for the Committee's consideration. IWG-1 was formed to develop recommendations regarding intra-service sharing among the proposed MSS systems and held 12 meetings; IWG-2 was formed to develop recommendations regarding inter-service sharing between MSS and other services operating in the proposed and adjacent frequency bands and held 9 meetings; IWG-3 was formed to develop recommendations regarding feeder link transmission links and inter-satellite links and held 11 meetings. (A schedule of the Committee and IWG meetings is attached as Appendix 3. The Committee's Work Program, discussing in greater detail the scope of the Committee and the delineation of IWG responsibilities, is attached as Appendix 4.)

Early Committee meetings focussed on establishing the Committee processes and on identifying the characteristics of MSS systems as presently envisioned. The Informal Working Groups were the relevant forums for identification of issues, conduct and evaluation of technical analyses, presentation of alternative points of view, and eventual convergence to agreement on recommendations and rules. Each IWG developed a detailed report to the Committee. Those reports contain technical information and analyses on the issues pertinent to developing rules and forming recommendations for the technical regulation and coordination of the mobile satellite service in the 1610/2483 MHz bands. The IWG reports (Annexes 1, 2, and 3) were provided as input documents to the Committee. The substantive portion of the later Committee meetings involved the introduction of relevant documents by the IWG Coordinators, technical discussions by the Committee on the issues raised by the documents, and decisions by the Committee on these issues. During its deliberations, the Committee addressed, from all represented perspectives, the various technical issues involved in accommodating the maximum number of service providers in this new satellite service. (A list of documents identified by the Committee as pertinent to its deliberations is attached as Appendix 5.) All Committee and IWG meetings were open to the public.

After discussion and evaluation, the Committee approved the body of this report and the rules and recommendations contained therein. The IWG reports in Annexes 1, 2, and 3, supplied by the respective IWGs, were not submitted for approval by the Committee.

The Committee's Facilitator was Dr. Edward F. Miller. The Working Group Coordinators were John T. Gilsenan (IWG-1), Edward E. Reinhart (IWG-2), and Steven W. Lett (IWG-3). Michael W. Mitchell was the Vice-Coordinator of IWG-2. The FCC's designated representative on the Committee was Thomas S. Tycz. The Committee's Designated Federal Officer was Fern J. Jarmulnek. Kathleen A. Campbell was the Committee's Administrative Assistant.

The Committee's recommendations are discussed in narrative form in Sections 2, 3, and 4, below, with each section corresponding to the work of each IWG. The proposed text of the new rules and specific recommendations are set forth in Section 5. Unless otherwise specified, all rules and recommendations in this report reflect the unanimous concurrence of the Committee members. Alternate views of Committee members are contained in several addenda.

2.0 INTRASERVICE SHARING

The work program of Informal Working Group 1 (IWG1) was defined in the introduction and in part A of the full committee work program (see Doc MSSAC-4 (Rev. 1) as follows:

- Develop recommendations for FCC Rules in 47 C.F.R. Part 25 that address the technical aspects related to the selection and authorization of applicants to provide U.S. mobile satellite service (MSS) and radiodetermination satellite service (RDSS) in the 1610-1626.5 MHz and 2483.5-2500 MHz bands, and to the shared use of those bands by authorized entities.

- Recommend modifications to the existing rules for those bands (47 C.F.R. § 25.141), or new rules as necessary, to maximize multiple entry and to avoid or resolve mutual exclusivity among the non-geostationary satellite applicants, and between proposed non-geostationary and proposed or authorized geostationary satellite systems, while maintaining the economic viability of the systems. The following compatibility cases should be considered:

  (1) CDMA vis-a-vis CDMA MSS/RDSS systems;
  (2) CDMA vis-a-vis FDMA/TDMA MSS/RDSS systems;
  (3) FDMA/TDMA vis-a-vis FDMA/TDMA MSS/RDSS systems;

sharing studies and by IWG2 for its work. A second ad hoc group convened by Mike Ward, AMSC, analyzed material concerning potential interference from the secondary downlinks in the 1613.8-1626.5 MHz band. As the two basic approaches were clearly defined, two drafting groups were established:

- IWG1 Drafting Group A (DG1A), chaired by Jay Ramasastry of Loral Qualcomm Satellite Services Inc., was given responsibility for all sharing issues under the full band interference sharing approach.

- IWG1 Drafting Group B (DG1B), chaired by Bill Borman, Motorola, addressed sharing issues involving band segmentation.

Each drafting group had liaison responsibilities with IWG2.

2.3 Intraservice sharing considerations were examined by IWG1 and the results follow:

The Committee was not able to reach full agreement on recommendations or modifications to the Commission's rules which would maximize multiple entry and avoid or resolve mutual exclusivity among the applicants.

Attachments 1 and 2 of Annex 1 provide the results of the deliberations of the Committee and will be useful to the FCC as the Rulemaking process continues. Attachment 1 describes the full band interference sharing and band segmentation approaches considered by the Committee as well as suggested technical rules and recommendations for full band interference sharing subscribed to by AMSC, Celsat, Constellation, Ellipsat, Loral/Qualcomm and TRW. Attachment 2 describes several band segmentation approaches also considered by the Committee as well as suggested technical rules and recommendations for the approach preferred by Motorola and is subscribed to by Motorola. Each attachment addresses intraservice sharing for several cases considered by the Committee. There was common agreement on several sections which appear in these attachments. These are discussed in the following paragraph.

Consensus was reached by the Committee on text that described the applicant and proposed systems as well as two basic approaches to sharing the 1610-1626.5 MHz and 2483.5-2500 MHz bands: full band interference sharing and band segmentation. It also agreed on technical sharing criteria that might be applied among mobile satellite system operators under full band interference sharing as well as proposed uplink out of band emission limits and uplink emission limits that could be applied under band segmentation for MSS systems. It also agreed on downlink out of band emission limits for the bands 2483.5-2500 MHz and 1613.8-1626.5 MHz. Attachments 1 and 2 contain agreed upon text in Sections 1, 2 and 3. It should be noted that Sections 2 and 3 of Attachment 2 contain only the text section 6 of the attached documents. There were also agreements reached in Section 7 of the attachments on the effects of sharing with services other than MSS/RDSS. Finally, although not included in agreed upon text, the participants in the Committee agreed that the choice of orbit was not material to the ability to share spectrum if parameters are chosen appropriately.

Note: IWG1-81 (final); MSSAC 41.6 (final) is entitled by its authors "Final Report of the Majority of Active Participants of Informal Working Group 1 to the Above 1 GHz Negotiated Rulemaking Committee" and is Attachment 1 of Annex 1. IWG1-85 (final); MSSAC 41.7 (final) is the "Report of Motorola on Band Segmentation Sharing" and is Attachment 2 of Annex 1.

3.0 INTERSERVICE SHARING ISSUES

3.1 Interservice Sharing Scenarios Considered

Based on the international allocation table as revised at WARC-92, there are a large number of interservice interference possibilities. These are tabulated in Table 3-1 for reference in describing the results of the Committee's work on interservice sharing issues.

Referring to Table 3-1, note that sharing cases in which the other services are the victims of interference from MSS/RDSS systems are listed in part A of the table; those where MSS/RDSS stations are the victims are listed in part B. In each part, cases involving the same victim service and frequency band are grouped together with "in-band" interference cases (where the interfering service lies within the same band as the victim service) listed before the "out-of-band" cases. In part B, each case except 16 corresponds to interference in the reverse direction from one of the cases in part A. This correspondence is indicated by adding the letter R to the case number from part A.

References in parentheses included with the title of each of the following subsections are to the reports of the drafting groups (DG) of IWG 2; viz, DG2A on protection of the RAS, DG2B on sharing with the ARNS, and DG2C on sharing with all other services. These reports are included as Attachments A, B, and C, respectively, to the final report of IWG 2 (Doc. MSSAC 42.7 (Rev. 5)).

3.2 Protection of the Radio Astronomy Service

3.2.1 Characteristics of the Radio Astronomy Service in the Relevant Frequency Allocations (DG2A Report §1.1)

The radio astronomy service (RAS) is defined in RR 55 as "a service involving the use of radio astronomy" which, in turn, is defined in RR 14 as "astronomy based on the reception of radio waves of cosmic origin." Since radio astronomy involves only radio consists of protecting it against unacceptable interference from the transmitters in other services.

Protection of the RAS is important because a substantial portion of what has been learned about the universe in the last 60 years is based on observations by radio astronomers of the line and continuum radiation spectra of cosmic radio sources. Such protection can be difficult to achieve because cosmic radiation emissions are similar to random noise in nature and have extremely low power flux levels at the Earth. On the other hand, radio astronomy observatories are usually located in remote areas well shielded from interference by terrain features, and observations in a frequency band are not always continuous.

The band 1610.6-1613.8 MHz is allocated to the RAS on a worldwide primary basis and is shared with primary allocations for MSS/RDSS uplinks and the aeronautical radionavigation service (ARNS). It is used at RA observatories to observe the spectral line of the hydroxyl molecule near 1612 MHz, which is considered by radio astronomers to be among the most important line below 275 GHz. The upper and lower band limits correspond to the maximum expected "blue shift" and "red shift" of this line due to the relative motion of the galactic sources. Observations include the use of very long baseline arrays (VLBA) to determine the angular size of the sources.

TABLE 3-1. IDENTIFICATION OF POSSIBLE INTERSERVICE SHARING PROBLEMS

	Interference to		Interference From	
Case	Service[6]	Band (MHz)	Service[6]	Band (MHz)
A. Interference to other services from MSS/RDSS				
1	RAS	1610.6-1613.8	MSS/RDSS↑	1610.6-1613.8
2	RAS	1610.6-1613.8	MSS/RDSS↑	<1610.6&>1613.8
3	RAS	1610.6-1613.8	Sec MSS↓	1613.8-1626.5
4	RAS	4990 -5000	MSS/RDSS↓	2483.5-2500
5	ARNS[1]	1610 -1626.5	MSS/RDSS↑	1610 -1626.5
6	ARNS[1]	1610 -1626.5	Sec MSS↓	1613.8-1626.5
7	ARNS/RNSS↓	1559 -1610	MSS/RDSS↑	1610 -1626.5
8	ARNS/RNSS↓	1559 -1610	Sec MSS↓	1613.8-1626.5
9	FS[2]	1610 -1626.5	MSS/RDSS↑	1610 -1626.5
10	Sec FS[3]	1610 -1626.5	Sec MSS↓	1613.8-1626.5
11	FS & MS	2483.5-2500	MSS/RDSS↓	2483.5-2500
12	FS & MS	2450 -2483.5	MSS/RDSS↓	2483.5-2500
13	FS[4] & MS[5]	2500 -2690	MSS/RDSS↓	2483.5-2500
14	BSS & FSS	2500 -2690	MSS/RDSS↓	2483.5-2500
15	RLS	2483.5-2500	MSS/RDSS↓	2483.5-2500
B. Interference to MSS/RDSS from other services				
5R	MSS/RDSS↑	1610 -1626.5	ARNS[1]	1610 -1626.5
9R	MSS/RDSS↑	1610 -1626.5	FS[2]	1610 -1626.5
10R	Sec MSS↓	1613.8-1626.5	Sec FS[3]	1610 -1626.5
11R	MSS/RDSS↓	2483.5-2500	FS & MS	2483.5-2500
12R	MSS/RDSS↓	2483.5-2500	FS & MS	2450 -2483.5
13R	MSS/RDSS↓	2483.5-2500	FS & MS[5]	2500 -2690
14R	MSS/RDSS↓	2483.5-2500	BSS & FSS	2500 -2690
15R	MSS/RDSS↓	2483.5-2500	RLS	2483.5-2500
16	MSS/RDSS↓	2483.5-2500	ISM	2400 -2500

Notes:

[1]Including airborne electronic aids to air navigation and any directly associated ground-based or satellite-borne facilities per RR 732.
[2]In 20 countries as listed in RR 730 (MOD WARC-92).
[3]In 29 countries as listed in RR 727.
[4]MMDS, ITFS, and OFS in the U.S.
[5]Except AMS.
[6]Abbreviations:

AMS	Aeronautical mobile service	MSS	Mobile-satellite service
ARNS	Aeronautical radionavigation service	OFS	Operational fixed service
BSS	Broadcasting-satellite service	RAS	Radioastronomy service
FS	Fixed service	RDSS	Radiodetermination-satellite service
FSS	Fixed-satellite service	RLS	Radiolocation service
ISM	Industrial, scientific, & medical	RNSS	Radionavigation-satellite service
ITFS	Instructional television fixed service	Sec	Secondary allocation
MMDS	Microwave multipoint distribution service	↑	Uplink

The band 4990-5000 MHz is allocated to the RAS worldwide on a primary basis as one of several bands used for the observation of continuum radiation. It is of interest here because it embraces the second harmonics of MSS/RDSS downlink transmissions in the 2483.5-2500 MHz band.

3.2.2 Existing Regulatory Protection of the RAS (DG2A Report §1.2)

A number of paragraphs of the radio regulations and footnotes to the allocation table apply to the protection of the RAS. Specific harmful interference limits are discussed in CCIR Recommendation 224-7.

3.2.3 Existing Interference to the RAS (DG2A Report §2.1)

In considering how to protect the RAS from MSS/RDSS interference at L- band, it should be noted that the RAS already suffers severe interference from the Russian GLONASS system, a worldwide satellite system for aeronautical radionavigation operating in the 1610-1616 MHz band under RR 732. Indeed, it is estimated that more than 90% of current RA measurements in the 1610.6-1613.8 MHz band are rendered unusable by interference when the GLONASS system is operating.

The RA community is conducting a series of meetings with the Russian administration to discuss possible ways to redesign the GLONASS system to reduce its interference to the RAS. This effort is relevant to the MSS because modifications to GLONASS that protect the RAS can also reduce the vulnerability of GLONASS to interference from the MSS.

3.2.4 Interference Protection Required by the RAS (DG2A Report §2.3) and Sites To Be Protected (DG2A Report §3)

The recommended protection limits for the RAS are specified in CCIR Report 224 as -238 dB(W/m^{2}Hz) in the 1610.6-1613.8 MHz band and -241 dB(W/m^{2}Hz) in the 4990-5000 MHz band. Observatories at which VLBA measurements are being made in the former band require somewhat less protection.

The locations and heights above mean sea level of the 16 radio astronomy sites in the U.S. (including Puerto Rico) that conduct L-band observations are listed in Table 3-1 of the DG2A Report. Of these, only five need to be protected to the -238 dB(W/m^{2}Hz) level; the remaining are VLBA sites. Outside the U.S., there are 17 sites equipped to observe at L-band; they are listed in Table 3-2 of the DG2A Report.

Radio astronomy sites need to be protected from MSS/RDSS transmissions at L-band only while conducting observations in this band. It is estimated that such observations will take place not more than 25% of the time. The RA community is willing to establish an advance notification procedure of observation schedules in the U.S. so that MSS/RDSS system operators will know when interference protection is needed at each site.

3.2.5 Approaches to Protection of the RAS (DG2A Report §5)

3.2.5.1 Case 1 - Protection of the RAS in the 1610.6-1613.8 MHz band from in-band MSS uplink transmissions (DG2A §5.1)

There are a number of techniques available to prevent unacceptable interference from MSS/RDSS systems into radio astronomy. With respect to the MSS/RDSS 1610-1626.5 MHz Earth-to-space transmissions, mobile terminals can be prohibited from transmitting in the 1610.6-1613.8 MHz RAS band when in the vicinity of radio astronomy sites during times of observation. It should be noted that MSS/RDSS

3.2.5.1.2 Beacon-actuated protection zone (DG2A Report §5.1.3)

As a alternative to protection zones of fixed radii, a beacon-actuated protection system offers a method of dynamically protecting (in real time) electromagnetic sensitive locations, such as radio astronomy sites, from in-band MSS mobile terminal (MES) uplink transmissions. Since it is not feasible to restrict the location of the MES and since RAS sites do not make observations in the 1610.6-1613.8 MHz band all the time, a beacon protection system appears to offer significant advantages over other potential RAS sharing solutions.

To implement such a system, one or more omnidirectional radio beacons could be placed near each radio astronomy site that will be conducting observations in the 1610.6-1613.8 MHz band. These beacons would only transmit a signal when such observations were in progress. The number of beacons needed at each site would depend on the location of the site and surrounding conditions. Some RAS sites could be equipped with just one beacon, while other sites might need two or more beacons in order to ensure that local conditions were not masking potential interference into the RAS antenna.

When first requesting a channel assignment from the MSS Control Center on the control channel (which is not in the shared and protected band), the MSS Control Center would determine whether there are any radio emission restrictions associated with RAS observations in that area. If not, the MES would be assigned a communication channel without any restriction on the use of frequencies. If restrictions are in effect in the area of the MES, and the MES receives a beacon signal, the MSS control center would assign the MES a communications channel outside the shared, protected band. Absent receipt of such a signal, MES channel assignment would again be made without restriction. For example, if the mobile unit is shielded from the beacon by propagation obstructions (e.g., intervening terrain), then it would not receive a beacon signal and transmissions would continue without restriction. In that event, the mobile unit would be able to communicate with the satellite on any channel, and the radio astronomy site would not be affected.

On the other hand, if the mobile unit receives a beacon signal, transmissions over certain frequencies may be automatically inhibited or the system control facility may decide when transmissions would be the beacons are turned on), while affording the flexibility of MSS terminals to operate virtually without restriction during other periods of time (i.e., when the beacons are turned off). A beacon system may also minimize the geographic protection areas around RAS sites during periods of observation by utilizing real RF boundaries in all directions. If an MSS terminal does not receive a beacon signal due to propagation losses or other real-world effects, then it will be able to uplink in any frequency channel. On the other hand, the reception of a beacon signal by an MSS terminal would only restrict that terminal's use of certain uplink channels during the period of time that the beacon remained on or the user moved out of range. The signal strength of the beacons could also be adjusted over time to reflect additional or reduced protection requirements as circumstances warranted.

However, there are several theoretical and practical concerns which must be worked out before a beacon system can be implemented as a alternative to protection zones of specified radius around designated radio astronomy observatories.

3.2.5.2 Case 2 - Protection of the RAS in the band 1610.6-1613.8 MHz from MSS/RDSS uplink transmissions outside this band (DG2A Report §5.1.2)

One of the proposed approaches to protect radio astronomy sites from MES out-of-band emissions (including spurious in this discussion) in the 1610.6-1613.8 MHz band is to employ fixed protection, or exclusion, zones similar to but smaller than those for in-band emissions. These zones would be based upon path loss calculations for each system's relevant operating characteristics, such as frequency plan and out-of-band emission levels.

An alternative approach would be to develop a chart relating separation distance from a radio astronomy site as a function of the MES emission level that would fall in the radio astronomy band. Either approach would only be utilized during periods of observations within the 1610.6-1613.8 MHz radio astronomy band.

A number of calculations were carried out to determine the appropriate size for out-of-band protection zones using two different models to represent over-the-horizon propagation losses. For example, using the parameters of the Globalstar MES, including its out-of-band suppression specifications and the topography surrounding the Green Bank Observatory, these calculations suggested that a single MES user could operate without interference to a non-VLBA site at a distance of more than 10 miles from the site when operating within 4.5 MHz of the edge of the RAS band, and could approach as close as 7 miles when operating at greater frequency separations.

However, this example provides only one approach to determining exclusion zones for an MSS system and is not intended to be a definitive determination of the protection radius. In an actual simulation, the latest available version of the chosen propagation model should be used, along with appropriate parameters (e.g., 100-m elevation for the feed of the Green Bank telescope, 10-percent interference probability level, etc.). Further, in order to take troposcatter propagation appropriately into account, model calculations have to be run well over the radio horizon, out to the 150- to 200-mile range.

3.2.5.3 Case 3 - Protection of the RAS in the 1610.6-1613.8 MHz band from MSS secondary downlinks in the band 1613.8-1626.5 (DG2A Report §5.2.1)

Only one of the current MSS/RDSS applicants has proposed to use the secondary downlink allocation. To protect the RAS from harmful interference below 1613.8 MHz, three measures are proposed.

The principal measure is to restrict downlink frequencies to a band whose lower edge is separated from the upper edge of the RAS band by a 2.2 MHz guard band.

Second, out-of-band emissions will be controlled by filtering on board the satellite and by selectively controlling the number of downlink channels near the bottom of the band during RA observations.

Third, to ensure that the foregoing steps are effective, a

3.3 Sharing between the MSS/RDSS and the Aeronautical Radionavigation Service (ARNS) and Radionavigation-Satellite Service (RNSS)

3.3.1 Relevant ARNS and RNSS Frequency Allocations and Interference Cases Considered

The frequency allocations and interference cases to be considered in this section are those listed in Table 3-1 for interference cases 5, 5R, 6, 7, and 8. The characteristics of the systems that use these allocations will be summarized in §3.3.2 and their interference protection requirements in §3.3.3. The Committee's assessment and analyses of each interference case and of possible approaches to solution are summarized for the five interference cases of interest in §§3.3.4 through 3.3.8 respectively.

3.3.2 Description of the Relevant ARNS and RNSS Systems (DG2B Report §§1.1, 1.2, 1.3, 1.5)

The GPS and GLONASS systems operate under the radionavigation-satellite (space-to-Earth) service allocation in the 1559-1610 MHz band; the GLONASS system also operates in the aeronautical radionavigation service allocation under RR 732. Significant development of both GPS and GLONASS started in the 1970s. The 1979 WARC allocated spectrum for GPS in response to a U.S. proposal. Initial satellites were launched in 1978 (GPS) and 1982 (GLONASS) for experimentation. While neither system has been declared operational, there are 4 block I (developmental), 9 block II, and 9 block IIA GPS satellites in operation. GLONASS has 15 satellites in operation at this time. Each system will have up to 24 satellites in operation at any given time when the systems are fully operational (1994 for GPS, 1995 for GLONASS).

GPS is a space-based positioning, velocity, and time system whose space segment, when fully operational, will be composed of 21 satellites (plus 3 operational spares) in six orbital planes. The satellites will operate in circular 20,200 km (10,900 nm) orbits at an inclination angle of 55° and with a 12-hour period. Each satellite will transmit on two right-hand circularly polarized frequencies L1 (1575.42 ± 1.023 MHz for C/A code) and L2 (1227.60 MHz). L1 will carry a precise (p) signal (provides the Precise Positioning Service (PPS) of ±10.23 MHz which is not available for public use) and a coarse/acquisition (C/A) signal which is used for the Standard Positioning Service (SPS). L2 will carry only a P signal of ±10.23 MHz. Superimposed on these signals will be navigation and system data including satellite ephemeris, atmospheric propagation correction data, and satellite clock bias information. The minimum signal level specified into a 3 dB linearly polarized user receiver antenna located near the ground with a 5° elevation is -160 dBW for SPS and -163 dBW for PPS.

The GLONASS satellite subsystem will include 24 satellites evenly one launch per 7 months of three satellites. The GLONASS functions are similar to GPS except that GPS uses one frequency for all satellites and GLONASS uses 24 frequencies (1602.5625 MHz for the first frequency with each center frequency 0.5625 MHz spacing above for L1). Each satellite has a bandwidth of ±0.511 MHz for C/A signal and ±5.11 MHz for precision signal which is not available for public use. The minimum signal level specified into a 3 dB linearly polarized user receiver antenna located near the ground with a 5° elevation angle is -161 dBW for SPS.

The user segment will consist of antennas and receiver-processors

3.3.3 Existing Regulatory Protection for GPS/GLONASS and Protection Sought by the Aviation Community (DG2B Report §§1.4, 1.5, 3)

MSS/RDSS and GLONASS operations in adjacent bands are mutually protected by RR 343, which requires that frequency assignments in both services be sufficiently removed from the common band edge (here, 1610 MHz) to prevent harmful levels of adjacent band interference.

MSS/RDSS and GLONASS operations within the 1610-1626.5 MHz band are governed by RR 731E and 731F. Footnote 731E to the allocation table provides that MSS/RDSS systems are subject to coordination under Resolution 46 (WARC-92), that the MES of such systems shall not radiate an e.i.r.p. density greater than -15 dB(W/4kHz) in the part of the band used by systems such as GLONASS operating in the ARNS under RR 732 or greater than -3 dB(W/4kHz) in the balance of the band unless agreed by affected administrations. Finally, RR 731E states that MSS stations shall not cause harmful interference or claim protection from stations operating under RR 732.

The Committee was not able to agree on an interpretation of RR 731E in connection with the requirement to protect GLONASS from harmful interference. Insofar as the protection of a radionavigation service is concerned, "harmful interference" is defined in RR 169 as "interference which endangers the functioning of a radionavigation service or other safety service . . ." There were two difficulties here.

The first is whether operating at or below the e.i.r.p. limits specified in RR 731E satisfied the obligation of MSS uplinks to protect GLONASS from harmful interference. The second is to identify what level is harmful to GLONASS. That level obviously depends on the design characteristics and interference susceptibility of the GLONASS receivers. ARINC Characteristic 743A (March 1992) did not take into account the possibility of operating cochannel with the MSS and can be updated to achieve greater levels of interference immunity.

The GPS/GLONASS receiver specifications are described further in connection with the analysis of sharing feasibility described below for interference case 5.

3.3.4 Case 5 - Protection of ARNS in the 1610-1626.5 MHz Band from MSS/RDSS Uplinks in this Band (DG2B Report §§2.1, 3)

The Committee reviewed a number of measurements and analyses to determine the general sensitivity of GPS/GLONASS receivers to interference, the maximum interfering e.i.r.p. that such receivers could allow under current specifications, and the level of interference that typical mobile earth station (MES) transmitters would produce at a GPS/GLONASS receiver. These investigations are

3.3.4.1 GPS/GLONASS interference susceptibility measurements (DG2B Report §2.1.1)

Comsat Labs and 3S-Navigation Inc. each recently conducted measurements on both Russian and prototype U.S. GPS/GLONASS aeronautical navigation receivers to investigate their susceptibility to in-band interference from uplink transmission of hand-held MSS terminals. Using "live" signals from GLONASS satellites, the variation of the receiver carrier-to-thermal noise density, C/N_0 vs time and the dependence of the ratio of carrier-to-(noise + interference) density $C/(N_0+I_0)$ on interference density I_0. Both CW and a simulated 600 kHz spread-spectrum signal (300 bps, random modulated (I/O) bit stream) were injected cochannel with the GLONASS signal.

The resultant plot of $C/(N_0+I_0)$ vs I_0/N_0 indicated that the former decreases with increasing interference at about a dB-for-dB rate. However, the effect of interference was somewhat less than that of an equivalent amount of thermal noise. Moreover, none of the navigation outputs from the receiver was affected by the injected interference until the receiver lost track or synchronization at a value of